Project Final Report

I. Title: Evaluation of the Sustainability of the Sea Cucumber Fishery in California

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II. Abstract

The two sea cucumber fisheries in California (*P. californicus* and *P. parvimensis*) have rapidly expanded in recent years, and at present there are no restrictions on catch. A large reason for the lack of management for these fisheries is that very little is known about the ecology of *P. californicus* and *P. parvimensis* and the extent to which their populations can withstand sustained fishing pressure. We addressed this problem by using an integrated, four-fold approach aimed at obtaining the biological information necessary to develop a sound management plan for these fisheries. First, we evaluated spatial and temporal patterns of abundance in *P. californicus* and *P. parvimensis* using long-term data obtained for monitoring purposes by various county and federal agencies in the southern California Bight. Second, we estimated the effects of fishing on the standing stocks of *P. parvimensis* with Before/After Impact/Control Paired analyses of fishery-independent monitoring data. The results of these analyses differed substantially from those obtained by analyzing fishery-dependent catch data. Third we supplemented historical data on abundance with field collections and surveys to better document various demographic and biological parameters critical to fishery management. Finally, we determined the extent to which size structure and abundance of *P. californicus* varies with depth and season.

III. Executive Summary

The two sea cucumber fisheries in California (*P. californicus* and *P. parvimensis*) have rapidly expanded in recent years, and at present there are no restrictions on catch. A large reason for the lack of management for these fisheries is that very little is known about the ecology of *P. californicus* and *P. parvimensis* and the extent to which their populations can withstand sustained fishing pressure. The primary objectives of this study were: (1) to evaluate the population status of these two species, (2) determine the extent to which populations of these two species are affected by fishing, and (3) collect information on distributions, size structure, seasonality, and various demographic parameters that is needed to develop a sound management plan for these two fisheries.

We examined historical changes in standing stocks of *Parastichopus californicus* using fishery-independent data obtained from the biological monitoring programs of four publicly owned waste-water treatment facilities, referred to as POTWs, (City of Los Angeles, Los Angeles County, Orange County, and City of San Diego), and from the Southern California Coastal Water Research Project (SCCWRP). These data showed a 50-60 % decline in abundance between 1994 and 1998. Declines were greatest in shallow depths. We found no correlation between the decline in abunbance and data on landings obtained from the California Department of Fish and Game. Historical changes in standing stocks of *Parastichopus*

parvimensus were evaluated using fishery independent data obtained from long-term monitoring by the National Park Service and the U. S. Geological Survey. Significant declines in *P. parvimensis* (ranging from 25 % to 100%) occurred at eight of 19 sites spread among five islands. Non-significant declines were observed at an additional seven sites while a 39% increase in abundance was observed at two non-take reserves. BACIP analyses implicated fishing as the cause of these declines. Despite these declines CPUE showed no significant trends at except at Santa Rosa Island where it actually increased. These results bring into question the validity of CPUE data for purpose of stock assessment.

Diving surveys at mainland and island sites showed distinct spatial and temporal patterns in the densities of *P. parvimensis* . Densities were generally higher along the mainland and greatest in the spring; animals largely disappeared in the fall. Minimal growth was observed over the course of a year in tagged individuals. The growth that was observed occurred occurring primarily in the spring, which is when gonads were found to be the most developed. Examination of *P. californicus* collected in monthly trawls off Goleta, CA indicated two spawning periods; one in March and a second one in June. Gonads and other internal organs reached maximum development in spring and were virtually absent in the late summer and fall. During fall and winter *P. californicus* were generally smaller and more abundant in shallow depths (~47 m) compared to deeper depths (~ 140 m). No differences in size among depths were observed in June indicating that larger animals may move into shallower water to spawn.

IV. Purpose

A. Description of Problem

Management of benthic fisheries is a difficult undertaking. Pertinent data are frequently not available and are always difficult and expensive to obtain. This is especially true for developing fisheries because funds for fishery research and management tend to be in extremely short supply. Paradoxically, this is also a time when a rational management plan is needed to prevent the over-exploitation that is generally detected in benthic fisheries only after it is too late to prevent a collapse. This is certainly the case for the two sea cucumber fisheries in California (*Parastichopus californicus* and *P. parvimensis*). These fisheries have been rapidly expanding in recent years yet very little is known about the ecology of *P. californicus* and *P. parvimensis* and the extent to which their populations can withstand sustained fishing pressure. This lack of information makes it impossible to develop a sound management plan for sustaining sea cucumber harvests. As a result, there are currently no restrictions on the catch of *P. californicus* and *P. parvimensis* in California Data on their abundance have been collected by a variety of local, state, and federal agencies that can provide valuable insight into the development of a sound management plan for the recent sea cucumber fisheries. Unfortunately, these agencies do not have the funds to analyze these data, and without critical analysis the value of previously collected data to fisheries management will never be realized.

B. Objective of Project

The overall objective of our project was to provide a biological basis for the management of a sustainable sea cucumber fishery in the northeast Pacific, especially in California. To achieve this objective we proposed to combine untapped sources of existing data that were collected for other purposes with additional sampling directed at filling in the gaps of missing information. More specifically, we proposed to: (1) document historical changes in standing stocks of *Parastichopus californicus* and *P. parvimensis* using existing, but previously

unanalyzed data , (2) estimate the effects of fishing on the standing stocks of *P. parvimensis* using Before/After Impact/Control Paired sample analyses, (3) collect monthly data on biological parameters critical to fishery management (e.g. relative allocation to reproduction, feeding, respiration, wall musculature), and (4) determine the extent to which size structure and abundance of *P. californicus* varies with depth and season.

V. Approach

A. Description of Work

1a. Historical changes in standing stocks of *Parastichopus californicus*

Fishery-independent data on the abundance of *Parastichopus californicus* were obtained from the biological monitoring programs of four publicly owned waste-water treatment facilities, referred to as POTWs, (City of Los Angeles, Los Angeles County, Orange County, and City of San Diego), and from the Southern California Coastal Water Research Project (SCCWRP). All data on abundances were collected with semi-balloon otter trawls, which consisted of a 7.6 meter headrope, a 8.8-m footrope; 3.8 cm body mesh; and a 1.3 cm cod-end mesh. The area of bottom sampled by a particular trawl was estimated by multiplying the distance trawled (speed x duration of trawl) by the width of the trawl swath (4.83 meters). Trawls were typically pulled along the bottom for about 10 minutes at speeds of about 2 knots, yielding a typical area per sample of about 2,900 m^2.

The biological monitoring programs for the POTWs have collected data quarterly at an array of stations surrounding each waste-water outfall for varying periods of time, ranging from the early 1970's to the present. Data were collected by SCCWRP in two geographically extensive surveys of the southern California Bight conducted in the late summers of 1994 and 1998. Data from both surveys were concentrated in areas near the mainland of southern California Bight, however in 1998, a number of sites near the northern and southern Channel Islands were also sampled. Data on sizes were also collected at a subset of the stations sampled during the 1998 survey.

Fishery-dependent data consisted of landings provided by the California Department of Fish and Game. Landings (pounds) for each vessel trip were recorded in 10 minute x 10 minute blocks (i.e. CDF&G Fish Blocks) whose dimensions are approximately 10 x 10 nautical miles.

Our analysis of historical trends of *Parastichopus californicus* stocks for this report is based on both fishery-independent and fishery dependent data. The analysis of fishery-independent data consists of characterizing the densities (individuals per hectare) of *Parastichopus californicus* in 1994 and 1998 in five regions for the southern California Bight mainland extending from Point Conception to the US/Mexico border. Region 1 extends from Point Conception to Port Hueneme; Region 2 extends from Port Hueneme to Pt. Dume; Region 3 extends from Pt. Dume to the Manhattan Beach pier and includes the City of Los Angeles Sanitation District; Region 4 extends from the Manhattan Beach pier to the San Gabriel river and includes the Sanitation Districts of Los Angeles County; Region 5 extends from the San Gabriel River to the mouth of the San Dieguito Lagoon and includes the Orange County Sanitation Districts; and Region 6 extends from the mouth of the San Dieguito Lagoon to the U.S. Mexico border and includes the City of San Diego Sanitation District. Data from each region were divided into three depth zones: inner shelf (10 – 25 meters), middle shelf (25 to 100 meters) and deep (100 – 200 meters). Analyses of longer-term data obtained from POTWs is ongoing and will not be reported here.

1b. Historical changes in standing stocks of *Parastichopus parvimensis*

Data on *Parastichopus parvimensis* abundance were collected at the five northern Channel Islands (San Miguel Island (SMI), Santa Rosa Island (SRI), Santa Cruz Island (SCI), Anacapa Island (ANI), and Santa Barbara Island (SBI)) and at nearby San Nicolas Island (SNI), Fig. 1). Approximately two-thirds of the *P. parvimensis* harvest in California has come from these six islands (California Department of Fish and Game CMASTER data). Data on *P. parvimensis* abundance from the northern Channel Islands were obtained from the National Park Service, who has collected data annually on the abundance of a wide variety of species that inhabit kelp forests at 16 sites on the five islands since 1982. Two of the sites on the north-east side of ANI (Landing Cove and Cathedral Cove) are in a marine reserve where fishing has not been allowed since 1978. Fishing is permitted at the other 14 sites. *P. parvimensis* abundance at each of the 16 sites was estimated from non-destructive sampling of non-cryptic individuals. Data were collected once per year in the summer (June to August) by divers in 1 or 2 m^2 quadrats (n = 12 to 40 quadrats per site), which were randomly placed within a permanent 100 m x 20 m sampling area that defined each site. Sites for long-term monitoring were not specifically chosen by the National Park Service for the purpose of monitoring *P. parvimensis* abundance, but rather were selected to represent the broad range of environmental conditions and biological assemblages in the park. Monitoring sites were generally located in areas of continuous reef with relatively low coverage of sand and cobble.

Comparable data on *Parastichopus parvimensis* abundance for five sites off SNI were obtained from the United States Geological Survey (USGS). The USGS has been conducting semi-annual (April and October) monitoring of the kelp forest communities at these sites since 1980. On each survey *P. parvimensis* are counted by divers in five permanent 10 m x 2 m quadrats at each site using a non-destructive sampling procedure similar to that employed by the National Park Service. We used only data from October surveys at San Nicolas Island in our analyses to maintain compatibility with annual data from the northern Channel Islands. Fishing is permitted at all sites at SNI.

2. The effects of fishing on the standing stocks of *P. parvimensis*

Before/After Control/Impact Paired (BACIP) analyses were done to estimate the effects of fishing on populations of *Parastichopus parvimensis* at the permanent monitoring sites on the six islands. In a BACIP design, Control and Impact sites are sampled concurrently on multiple dates before and after an impact occurs. Each survey date during the Before period provides an estimate of the spatial difference between the Impact and Control sites. Continued sampling during the After period yields a time series of differences between the Impact and Control sites from the Before and After periods. The mean difference between the Impact and Control sites in the Before period is compared statistically to that in the After period using a *t* test to determine whether there has been an impact and the relative size of its effect.

In our analyses the impact is the commercial dive fishery for *Parastichopus parvimensis*. The start of the commercial fishery marked the beginning of the After period and was defined for each island as the year in which the cumulative catch equaled of exceeded 5 % of the total cumulative catch through 1999. The no-take reserves at Landing Cove and Cathedral Cove on ANI served as our Control (non-fished) sites while all other sites were considered Impact (i.e. fished) sites that varied in their intensity of fishing pressure. We used the mean annual abundance of *P. parvimensis* at Landing and Cathedral Coves as the control in all BACI

analyses. Separate BACIP analyses were done for each fished site. *T* tests in all BACIP analyses were one-tailed to test the null hypothesis that fishing did not cause a decline in the abundance of *P. parvimensis.*

Stock assessment based on fishery dependent data such as catch is often suspect. To evaluate whether this was true for the warty sea cucumber fishery we compared results on the status of the fishery based on long-term population monitoring and BACIP analyses to those estimated by data on CPUE obtained from the California Department of Fish and Game.

3. Biological and demographic data

P. parvimensis

We studied *P. parvimensis* at two sites in the Santa Barbara Channel off the coast of southern California. The mainland site (34° 25.63' N, 119° 55.43' W) is an isolated artificial patch reef that lies approximately 500 m east of Ellwood Pier. The island site (34° 02.00' N, 119° 42.08' W) is located on the north-eastern side of Santa Cruz Island, California and is a portion of a prolific, continuous rocky wall that drops steeply from the shore to roughly 13 m depth. We measured seasonal changes in the density of *P. parvimensis* by surveying each site monthly for one year from October 1998 to October 1999. Divers counted the number of *P. parvimensis* in five 10 m x 2 m band transects at the mainland site and ten 5m x 2 m band transects at the island site, for a total area surveyed of 100 m^2 at each site. Growth was followed in tagged individuals at both sites by recording their contracted length and width on repeated surveys. A total of 771 individuals were tagged at the mainland site and 453 at the island site Recapture rates were 26.1 % and 2.6 % for the mainland and island sites, respectively. Developmental rates of larvae were measured in laboratory. Larvae were maintained at 16 ^oC and on a diet of *Dunaliella tertiolecta.* Seasonal variation in the availability of food was estimated monthly (from November 1998 to October 1999) on five replicate 10 cm x 10 cm rock plates at both the island and mainland study sites. Rock plates and the sediments on them were collected each month, and replaced with new rock plates. Divers carefully placed the collected plates placed in water tight containers and returned to the laboratory where they were scraped with a brush and rinsed. All rinse water and the seawater that accompanied the rocks in the closed containers were filtered through 0.2 micron glass fiber filters. Half of each filter was used to estimate ash free dry weight and the other half was analyzed for carbon and nitrogen.

Changes in body condition in *P. parvimensis* were assayed monthly from November 1998 to October 1999. Thirty *P. parvimensis* were collected by divers from a rocky reef approximately one km from the island site. The collection site was similar in habitat and sea cucumber density to the island site but was far enough away so that collections there would not affect density measurements at the island site. For each monthly batch of sea cucumbers, we measured contracted length (to the nearest 0.5 cm), contracted width (to the nearest 0.5 mm), and wet weight (to the nearest g) of live, turgid animals.. Each animal was then dissected, and the digestive tract, respiratory tree, and gonad were removed. Gut contents were removed from the digestive tract. The wet body wall, digestive tract, respiratory tree, and gonad were all weighed separately, dried in an oven at 70 °C until constant weight was reached, and then weighed again. Gonad index was calculated as dry gonad weight (g)/dry body wall weight (g) x 100.

P. californicus

Commercial fisherman from Santa Barbara provided us with 30 individuals each month during the period September 1998 – September 1999. *P. californicus* were picked up at the

dock placed in individual ziplock bags, put on ice and transported to the marine laboratory at UCSB where they were measured (contracted length and width) and weighed (whole wet weight) prior to being dissected. After dissection, the following data were collected for each individual:, wet and dry weight of gonadal tissue, wet and dry weight of body wall musculature, wet and dry weight of digestive tissue, wet and dry weight of respiratory tree. From these data the following indices were calculated for each sampling date: mean gonad index (gonad wt / wt. of the sum of all parts), mean body wall musculature index, mean gut index, mean respiratory tree index.

4. The relationship of season and depth on the size structure and abundance of *P. californicus*

Trawls were done on three dates (September 23, 1999, January 15, 2000 and June 1, 2000) at three locations (depths) off the coast of Goleta, CA to determine the extent to which the abundance and size of *P. californicus* varies with season and depth. The average depths of the three sites were 47 m, 57 m and 139m. All tows were 20 minutes in duration and the area trawled on each tow was assumed to be similar. The contracted lengths of all *P. californicus* caught in each trawl were recorded. All animals were returned to the sea after being measured.

B. Project Management

Dr. Stephen Schroeter, Co-Principal Investigator: Dr. Schroeter was responsible for (1) assimilating and analyzing the historical data on sea cucumber abundance and catch statistic, and (2) evaluating the effects of fishing on stock size in *P. parvimensis* abundance He worked closely with representatives of many different agencies from whom the data were obtained.

Dr. Dan Reed, Co-Principal Investigator. Dr. Reed was responsible for project administration, supervising the collection of new data, data analysis, report writing, and mentoring students working on the project.

Dr. John Dixon, Co-Principal Investigator. Dr. Dixon had a large part in writing the proposal that was funded to do this work. He left UCSB shortly after the project started to accept a position with the California Coastal Commission. Consequently he was not involved in the research done on this project.

Mr. John Richards, Associate Research Biologist. Mr. Richards served as a liason with the commercial trawl fisherman who collaborated with us on this project. He was responsible for organizing the monthly trawls, collecting samples from the fisherman and assisting in the processing of these samples.

Dr. Ginny Eckert, graduate student. Dr. Eckert was funded to conduct field and laboratory studies aimed at obtaining key demographic information on *P. parvimenis*. The work required a considerable amount of diving and laboratory processing of samples collected in the field. She was responsible for supervising a team of undergraduate assistants, analyzing data and writing it up for publication. Dr. Eckert completed her Ph.D. near the end of project and accepted a position as Assistant Professor at the University of Alaska, Juneau. She is currently preparing a manuscript on the results of the work she conducted on this project.

Ms. Dianna, Pinkard, Undergraduate student and Laboratory Assistant. Ms. Pinkard was responsible for (1) processing sea cucumbers for data on reproductive condition, developmental

state of digestive tract and respiratory tree, and body wall musculature, (2) diving surveys, and (3) data entry and quality control.

Ms. Betty Little, Laboratory Assistant. Ms. Little assisted in the processing and dissecting of sea cucumbers.

Mr. Matthew Knoppe, Laboratory Assistant. Mr. Knoppe work as a diver and assisted in the demographic studies on *P. parvimenis*

Ms. Carey Galst, Undergraduate research assistant. Ms. Galst assisted in laboratory growth studies and data entry.

Mr. Lee Hun, Undergraduate research assistant. Mr. Hun assisted in the processing and dissecting of sea cucumbers.

Ms. Ashleigh Rossman, Undergraduate research assistant. Ms. Rossman assisted in laboratory growth studies.

Many individuals representing various agencies were not employed on the project, but collaborated with us in this research. They include: Mr. David Ono, California Department of Fish and Game; Mr. David Kushner, National Park Service; Dr. James Estes, U.S. Geological Survey; Drs. Jim Allen and Stephen Weisberg, Southern California Coastal Water Research Project (SCCWRP); Mr. Mike McCorkle, commercial fisherman.

VI. Findings

A Actual Accomplishments and Findings

1a. Historical changes in standing stocks of *Parastichopus californicus*

There was a significant overall decrease in the abundance of *P. californicus* within the southern California Bight between 1994 and 1998 (20.9 to 10.6 hectare^{-1}). In both years, most of the standing stock was concentrated in regions 1, 3, and 6. In 1994, abundance was highest in region 3 (59.3 hectare^{-1}) followed by regions 1 and 6 (26.5 and 22 hectare^{-1}, respectively). Ranking of regional abundances was the same in 1998, but abundances had declined between 47% (region 1) and 60% (regions 3 and 6) from the 1994 levels. In 1994, abundances were highest in middle shelf depths (39.7 hectare^{-1}), followed by deep sites (25.3 hectare^{-1}). Cucumbers were absent at the shallow shelf sites. The ranking by depth zone was the same in 1998, but abundances in deep and mid-shelf sites dropped markedly (by 40% and 54 %, respectively), while abundance at shallow shelf sites increased (0 to 2.2 hectare^{-1}).

Harvesting by trawling began in the late 1970's, was low and sporadic until the late 1980's, and then increased abruptly between 1991-1995. From 1997 – 1999, harvests dropped to levels seen in the late 1980's. Analysis of trawl harvests within the southern California Bight from 1980 through 1999 showed that most of the sea cucumber harvest occurred at fish blocks away from waste water outfalls (93.3%). The highest proportions of harvest occurred near the Santa Barbara outfall (4.9%), followed by the Orange County outfall (1.5%). Harvests near the other waste water outfalls together accounted for less than 0.5% of the total harvest. Based on this finding, future analyses will focus on comparing longer term temporal patterns of abundance between areas near the more or less impacted waste-water outfalls.

The possible relationship between harvesting and declines in cucumber abundance were investigated by examining correlations between the changes in abundance between 1994 and 1998 and the cumulative harvest through 1997 by region. Unfortunately, the low spatial resolution of the fishery dependent data made it impossible to take into account the strong depth related declines seen in the fishery independent data. We found no relationship between the various measures of cumulative catch and changes in abundance between 1994 and 1998 ($-.25 < r < -0.07$; $.5 < p < .8$). The pattern of change in abundance with depth (declines within trawl depths versus no declines or increases at sites shallower than trawl depths) suggest fishing has had an impact on cucumber stocks.

1b. Historical changes in standing stocks of *Parastichopus parvimensis*

Kelp forest monitoring data suggest that the abundance of *Parastichopus parvimensis* decreased throughout the islands following the onset of fishing. Within three to six years of the start of the fishery, significant declines in sea cucumber abundance (ranging from 25 % to 100%) occurred at eight of 19 sites spread among five islands. An additional seven sites showed non-significant (i.e., $P > 0.05$) reductions in sea cucumber abundance, while four sites showed non-significant increases. In contrast, a significant 39 % increase in the abundance of *P. parvimensis* at the two non-fished reserve sites occurred after 1995, which marked the onset of fishing at ANI, SNI and SMI. Increases observed in the abundance of *P parvimensis* at the non-fished reserve sites were not significant when the start of the fishery was assumed to be 1993 or 1997, which marked the start of the fishery for SCI & SRI, and SBI respectively.

2. The effects of fishing on the standing stocks of *P. parvimensis*

Only seven of the 19 fished sites met the underlying assumptions of BACIP. The use of BACIP to estimate impacts from fishing was excluded at nine sites because the data in the Before period were non-additive. Non-additivity can be expected in cases where abundance at the impact site is consistently much lower than at the control site. Under such conditions, the difference between impact and control sites will be much greater during years when sea cucumber abundance is generally high compared to years when sea cucumber abundance is generally low. Such was the case for eight of the nine sites that failed to meet the assumption of additivity. These eight sites were probably not subjected to intensive fishing pressure due to their inherently low sea cucumber stocks, and they showed no significant difference in sea cucumber abundance between the Before and After periods (in all cases $P > 0.10$). Pelican Bay on Santa Cruz Island was the lone exception to this rule as data from this site were non-additive despite relatively high abundances in the Before period. The high densities of *Parastichopus parvimensis* at Pelican Bay and its close proximity to mainland ports make it an attractive site for fishing. The significant 65% decline in sea cucumber abundance observed at this site from the Before to After periods coupled with the high landings reported for Santa Cruz Island suggest that it was probably heavily fished. Three additional sites with relatively high densities of *P. parvimensis* (Nav Fac, Admiral's Reef, and Gull Island) were excluded from analyses using BACIP because they showed positive trends in abundance during the Before period.

All seven sites that met the underlying assumptions of BACIP showed significant negative effects of fishing. The decline in the relative abundance of *Parastichopus parvimensis* at these sites (as estimated by BACIP) ranged from 33 % to 83 %. The smallest relative decline occurred at Johnson's Lee South, which supported sparse densities of *P. parvimensis* relative to the other six sites evaluated using BACIP. This was the only one of the seven sites that did not

show a significant decline in the absolute abundance of *P. parvimensis* from the Before to After period . The density of *P. parvimensis* at the other six sites declined by 25% to 67% following the onset of fishing.

An evaluation of *Parastichopus parvimensis* stocks based on analyses using fishery dependent data contrasted sharply with that based on BACIP and Before/After analyses of fishery independent data. CPUE did not decline at any of the six islands during the three to six year period following the onset of fishing despite a general decline in *P. parvimensis* abundance during this time. Surprisingly, Santa Rosa Island actually showed a significant increasing trend in CPUE. These results highlight the danger of relying on catch data for purposes of stock assessment.

3. Biological and demographic data

P. parvimensis

There were distinct spatial and temporal patterns in the densities of sea cucumbers found at the island and mainland sites. At both sites sea cucumber densities were lowest in the fall and highest in the spring with the greatest density occurring in June. Densities were generally higher at the mainland site compared to the island site. Relatively few individuals displayed significant growth between summer and the following spring. Only 8 % of the tagged individuals at the mainland site that were measured in summer 1998, and re-measured in spring 1999 showed an increase in contracted length; 82 % showed a decrease in contracted length and 10 % showed no change (n=72 individuals). A greater percentage of individuals grew during the spring. Of sea cucumbers measured in spring 1999, and then again in late summer 1999, 36% increased in length, 52% decreased, and 12% did not change in length (n=82). Of the sea cucumbers at the island site measured during the initial tagging effort in summer 1998 and then again one year later in late summer 1999, 13% were longer, 80% were shorter, and 7% showed no change in length (n=45). Larval culture studies showed that the blastula stage was reached within 18 hours after the addition of sperm, gastulation occurred within 42 hours, and larvae were fully developed within 84 hours. Settlement of free swimming larvae occurred approximately 34 days post fertilization

We found little temporal variation in the nutritional value of sediments that accumulated on experimental rocks. The mean total ash-free dry weight and C:N ratio of sediments did not change significantly over the course of the experiment. There was no relationship of sediment content with sea cucumber activity patterns or reproductive cycle. Reproduction (as estimated by gonad index) peaked in April declined to zero by June and remained low through October when the study ended. The smallest sea cucumber found with gonads (i.e. the size of first reproduction) in April, the month of highest gonad index, had a contracted length of 11cm and dry wall weight of 13.8g.

P. californicus

There appear to be two spawning periods in *P. californicus* based on relative gonad size The first occurred in March. Gonadal tissue was completely absent in *P. californicus* from July through September. Regeneration of gonads began in October and peak in March, which was followed by a slightly smaller peak in June. These data suggest that within a given year, individuals undergo two spawning bouts in the spring. During the fall and early winter when gonadal tissue is being regenerated, the digestive and respiratory systems are in a state of atrophy. Gut and respiratory tissue are regenerated in the winter and are at their maximum

development in spring during the height of the reproductive system. Not surprisingly, the body wall musculature constitutes a proportionally smaller amount of the total biomass in the spring when other internal tissues are at their maximum development.

4. The relationship of season and depth on the size structure and abundance of *P. californicus*

Trawl data indicate that *P. californicus* are usually smaller and much more abundant in shallower depths. This pattern, however was not consistent throughout the year. The mean size of cucumbers at the two shallowest sites increased to that of the deeper site in June. This finding suggests that larger *P. californicus* move into shallower depths during the spring when peak spawning occurs. Interestingly, *P. californicus* was nearly tens times more abundant at the 47 m site compared to the 139 m site at all times of the year.

B Significant Problems That Resulted in Less Than Satisfactory Results.

It took longer than expected to obtain historical data on the abundance of *P. californicus*. Consequently, analyses of these data are still ongoing.

C Description of Need for Additional Work

Continued analyses of the data on the abundance of *P. californicus* and *P. parvimensis* data from the ongoing long-term monitoring programs is needed to evaluate future changes in stock abundance of these two species.

VII. Evaluation

A. Extent to which project objectives were attained.

Nearly all of our project objectives were attained. We initially had hoped that we could perform a BACIP analysis to evaluate the effects of fishing on *P. californicus* using SCCWRP's long-term monitoring data. However, this did not prove feasible because analyses of the catch data revealed that there has been very little fishing in the areas of SCCWRP's monitoring sites.

B. Dissemination of Project Results

We have submitted a paper (entitled "The use of marine reserves in evaluating the dive fishery for the warty sea cucumber (*Parastichopus parvimensis*) in California, USA" by Stephen C. Schroeter, Daniel C. Reed, David J. Kushner, James A. Estes, and David S. Ono) for publication to Canadian Journal of Fisheries and Aquatic Sciences on our research that investigated the effects of fishing on the standing stocks of *P. parvimensis* using Before/After Impact/Control Paired analyses. We also presented this work at two scientific meetings, the southern California Academy of Sciences held in May 2000 in Los Angeles, and the Temperate Reef Symposium held in February 2000 in Cape Town, South Africa..

We are currently preparing two additional manuscripts for publication in scientific journals; one paper will focus on our demographic studies of ***Parastichopus parvimensis***, and the other one will detail spatial and temporal patterns of abundance, size, and physiological condition of *P. californicus.*

We have worked closely with the California Department of Fish and Game throughout this study and we will make all of our results available to them to aid them in developing a sound management plan for these fisheries.